CHAPTER VIII

CANOPY TEMPERATURE OF SEVERAL CORN HYBRIDS IN RESPONSE TO WATER STRESS AND PLANT POPULATION

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ABSTRACT

Canopy temperature (T_{IR}) was measured with an infrared thermometer on nine different hybrids of corn (Zea mays L.) during 1978 and 1979. Three irrigation treatments were used to develop water stress across a plot at different stages of growth. In 1979 plots were planted at four plant population levels and subjected to several irrigation regimes.

The objectives of this study were 1) to relate grain yields of the various hybrids to crop temperatures that develop in response to water stress and 2) to determine how plant population interacts with water stress to determine canopy temperature.

The yield in all of the nine hybrids was reduced to about the same degree below that in fully irrigated corn. Estimation of yield reductions due to water stress requires knowledge of the maximum yield potential of the hybrid under fully irrigated conditions and of the degree of crop stress, which can be calculated in terms of TSD values (TSD is defined as the mid-day canopy temperature difference between well-watered and stressed plants). Our results suggest that a temperature stress day of 1 C predicts a yield reduction of about 0.7%.

Under fully irrigated conditions values of T_{IR} were not influenced by plant population. Under water stress conditions, T_{IR} values were consistently 1-2 C higher with high plant populations

than with low plant population. This higher canopy temperature is attributed to greater competition in areas of higher population leading to more rapid depletion of available water.

INTRODUCTION

Gardner et al. (Chapter VI) reported a similar relationship between crop temperature and the percent grain-yield reductions caused by water stress in two sorghum hybrids. This finding is encouraging to those who wish to estimate grain yield potential with remote sensing techniques. The purposes of the study reported here were 1) to study the response of grain yield in nine hybrids of corn (*Zea mays* L.) to crop temperature regimes caused by a range of water stress conditions and 2) to determine the extent to which plant population interacts with water stress to affect crop canopy temperature.

MATERIALS AND METHODS

This study was conducted during 1978 and 1979 at the University of Nebraska Sandhills Laboratory, near Tryon, Nebraska (41° 37' N; 100° 50' W; 975 m above mean sea level). Details of the irrigation system which was used in the study to evaluate the response of the nine corn hybrids to water stress are given in Chapter II. In 1978, three hybrids of corn: Dekalb XL-15A, Pioneer 3148 and Prairie Valley 215 were planted in plots measuring 9 m (N to S) and 19 m (E to W) (Fig. 1). Two irrigation treatments were used: I-G-I and G-G-I where I stands for full irrigation and G stands for a gradient irrigation of a plot during either the vegetative, pollination or grain-fill periods. In the G treatment, the side of the plot near the irrigation line

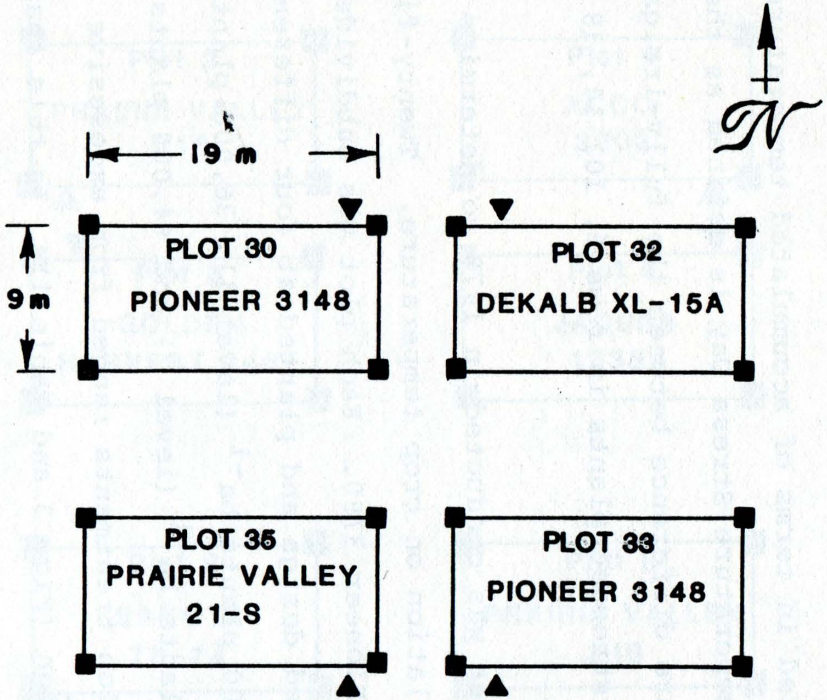

Fig. 1. Map of the plots used in the 1978 corn hybrid study. Locations of the solid-set sprinklers are represented by squares. The triangles show locations of the fully irrigated row when an irrigation gradient was applied.

receives full irrigation and the other side receives no irrigation. The nine plots of Pioneer 3780 described in Chapter II were also included in this study. In 1979, five corn hybrids: Jacques 1033A, Prairie Valley 21 S, Sokota TS 74, Acco 3002 and Golden Harvest 2457 were planted in 9 m (N to S) by 19 m (E to W) plots (Fig. 2). All plots were irrigated with a G-I-G treatment. The percent reduction in yields of each of these hybrids due to water stress was evaluated in terms of accumulated temperature stress days (TSD). A Temperature Stress Day is defined as the mid-day canopy temperature difference between the fully-irrigated plants in row 2 and the stressed plants in rows 6, 10, 14, 18 or 22.

A separate experiment was conducted in 1979 to determine the effect of plant population on crop temperature. Twenty-five plots were planted with Pioneer 3780. Each plot was subdivided in a completely randomized design and planted at four different population levels: 26,000 plants ha^{-1} (level 1), 36,000 plants ha^{-1} (level 2), 54,000 plants ha^{-1} (level 3) and 64,000 plants ha^{-1} (level 4). Irrigation treatments ranged from excesssive irrigation to no irrigation (Fig. 3 and Table 1). In this chapter, we report only the data collected in plots 23, 27, 29 and 32 (Fig. 3).

Infrared thermometer (IRT) measurements were made with a Barnes PRT-5[1] in 1978 and a Telatemp model Ag 42[2] in 1979. In both years measurements began at the beginning of the pollination

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[1]Barnes Engineering Co., 30 Commerce Rd., Stamford, CT.

[2]Telatemp Corp., P.O. Box 5160, Fullerton, CA.

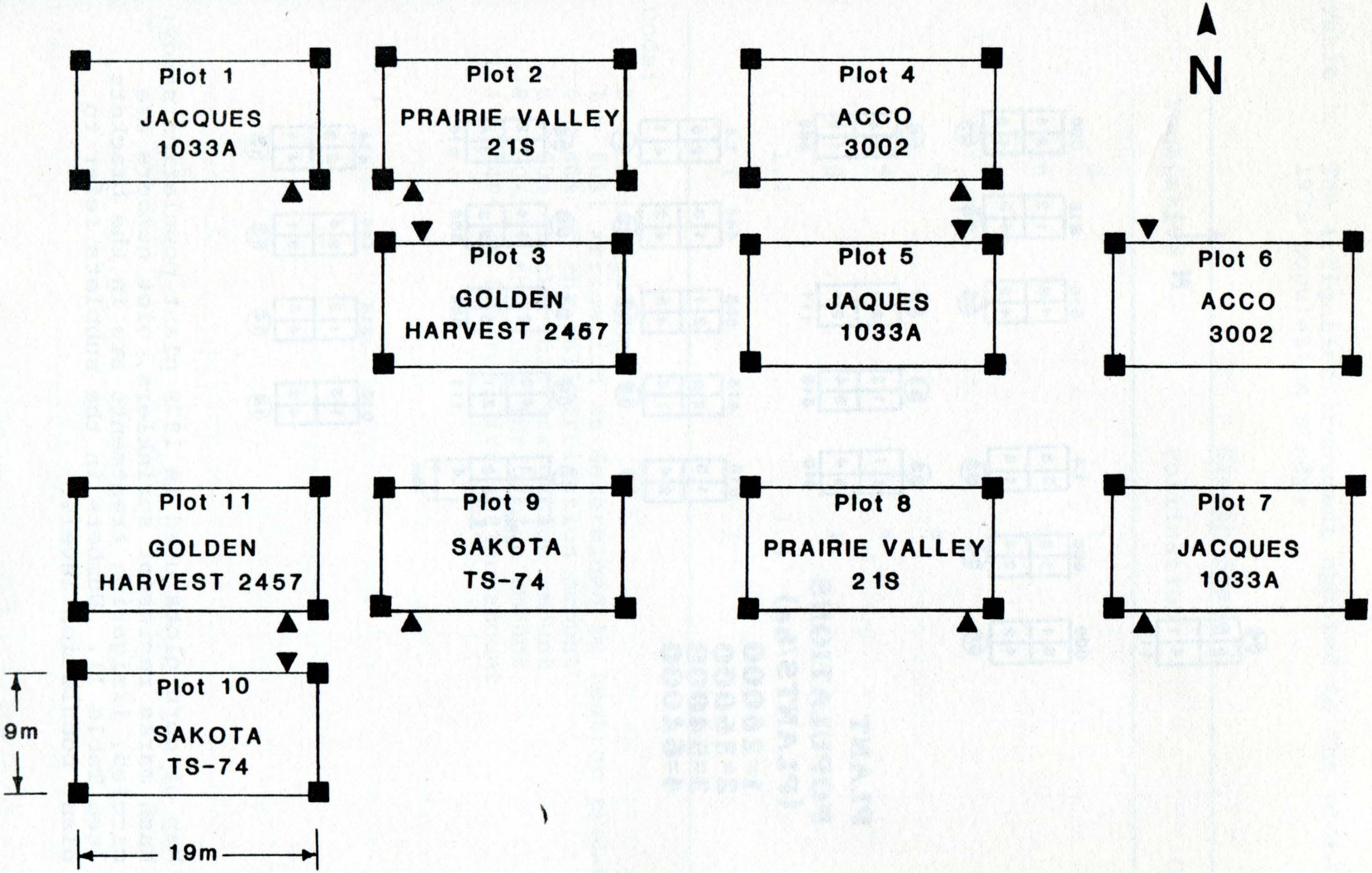

Fig. 2. Map of eleven plots used in the 1979 corn hybrid study. Symbols are the same as in Fig. 1.

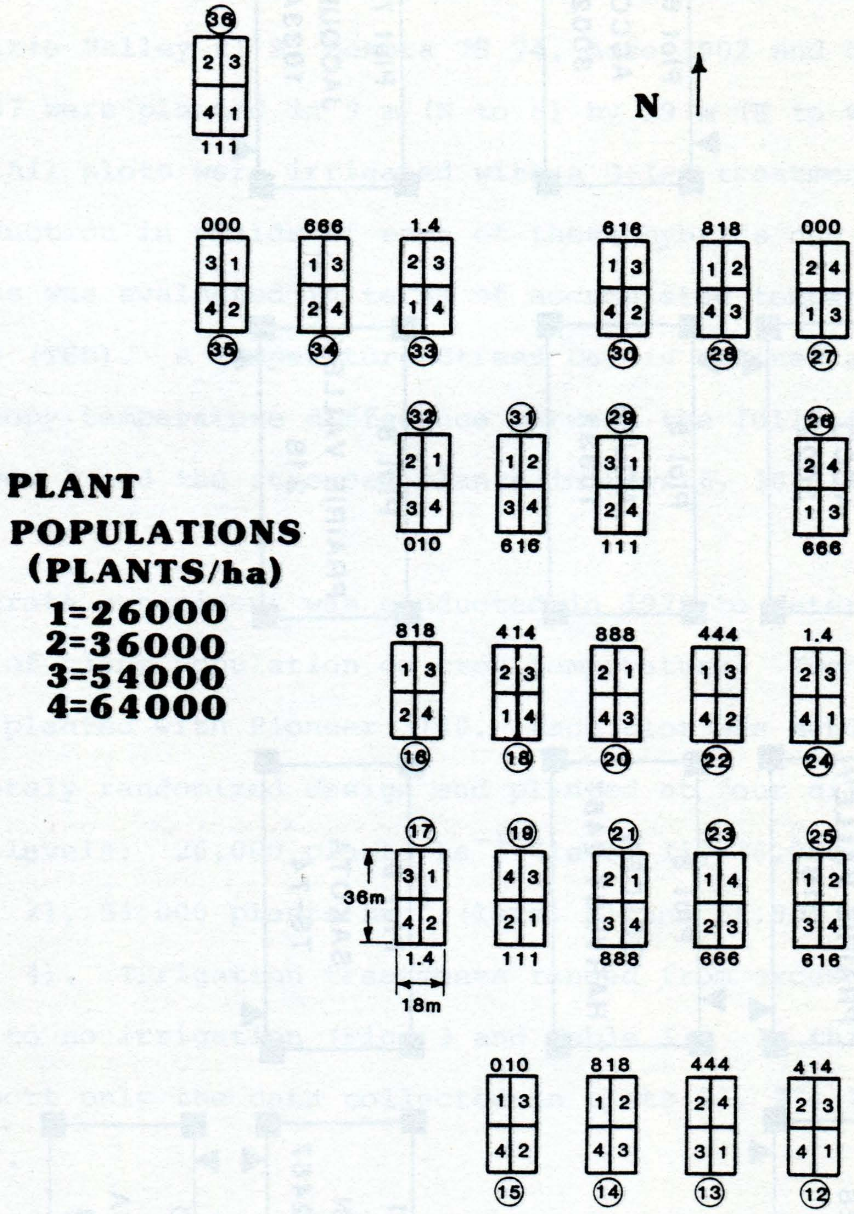

Fig. 3. Map of corn plots used in 1979 plant population study. Hash marks represent sprinklers, plot numbers are circled, irrigation treatments are in the brackets (see Table 1). Numbers in the subplots refer to plant population levels.

Table 1. The irrigation treatment applied to the plots in the 1979 population study.

Growth Stage		
Vegetative	Pollination	Grain Fill
0	1	0
6	1	6
6	6	6
8	8	8
4	4	4
8	1	8
1.4	1.4	1.4
1	1	1

Code:
0 = no irrigation
1 = full irrigation as determined by neutron probe sampling
4 = 40% of the full irrigation amount
6 = 60% of the full irrigation amount
8 = 80% of the full irrigation amount
1.4 = 140% of the full irrigation amount

stage in all varieties. IRT measurements were made between 1300 and 1500 hrs on almost every day throughout the remainder of the season.

A hailstorm, with stones up to 3 cm in diameter, struck the experimental site on July 16. Many of the emerged leaves, were shredded but stalk damage was minimal. This damage altered the plant canopy and may have permitted the IRT to view deeper into the plant canopy, especially with gusty winds. The temperature variability due to wind gusts alone was, subsequently, estimated to be approximately 0.5 C (Chapter IX). Since the effect of wind gusts should be random in nature, we interpreted measured temperature differences of 1 C or more to be real.

RESULTS AND DISCUSSION

Hybrid Study

Only small grain yield reductions occurred in the various corn hybrids in response to increased canopy temperature caused by water stress. The percent yield reduction (Fig. 4) is about the same for all hybrids at a given value of ΣTSD. Most yield values are within ±5% of the curve fitted in the figure by polynomial regression. Virtually all values are within ±10%. The quadratic term of the equation appeared to have little effect except at large values of ΣTSD so that a linear regression was deemed adequate to describe the relationship. This resulted in a slight reduction in R^2 from 0.91 to 0.87. We calculated that, based upon slope of the linear regression line, about 0.7% of the maximum yield potential (yield achieved with no water stress) is lost for each unit of ΣTSD experienced by the corn.

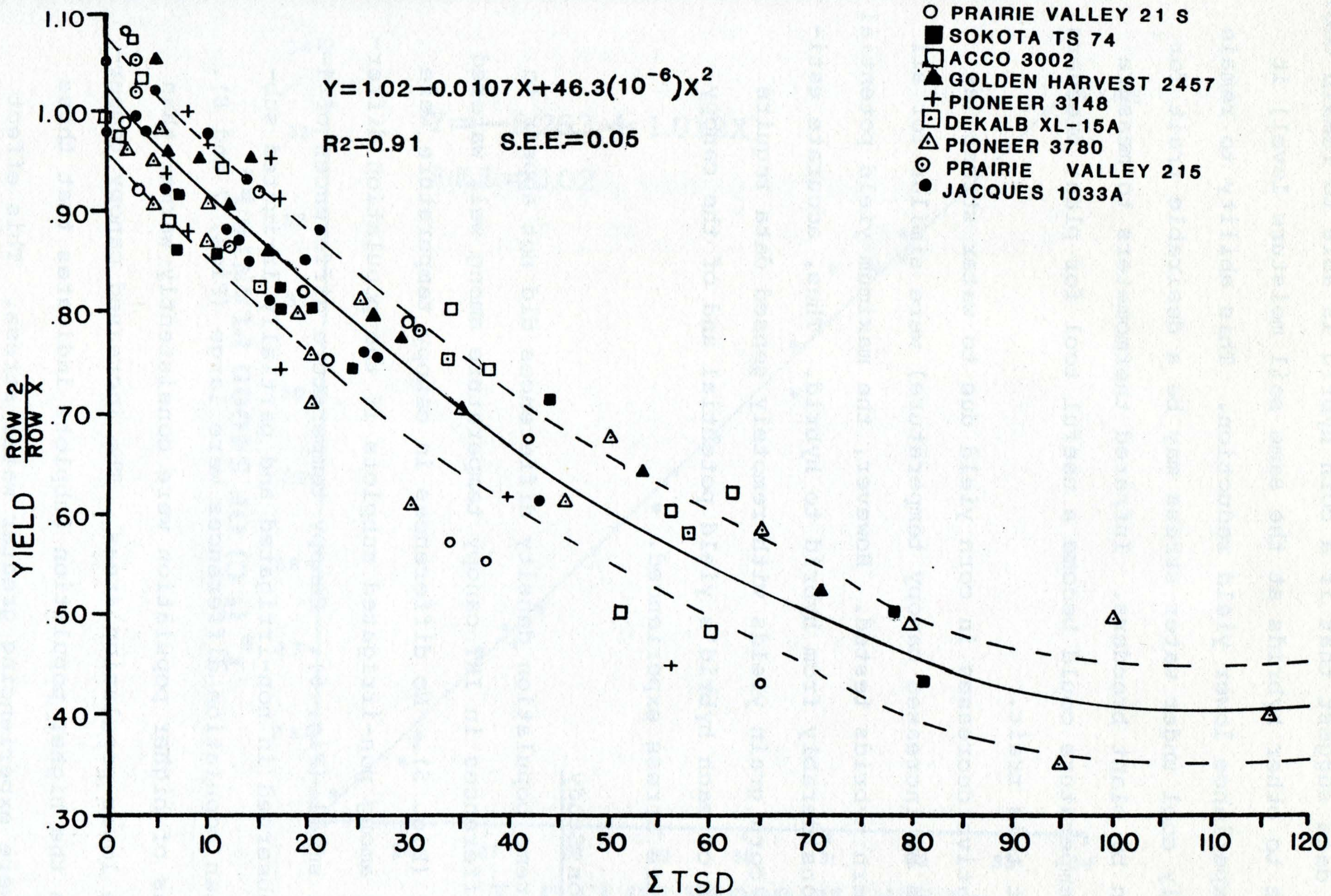

Fig. 4. Comparison of grain yields, as a fraction of the row 2 (fully irrigated) yields, for nine corn hybrids as a function of ΣTSD values. Crop temperature data used to obtain ΣTSD values were obtained during the pollination and grain-fill periods. Dashed lines indicate the standard error of estimate.

The data suggest that if a corn hybrid is able to remain cool (relative to other hybrids at the same soil moisture level) it should experience lower yield reduction. This ability to remain relatively cool under water stress may be a desirable trait for selection by plant breeders. Infrared thermometers to measure canopy temperature could become a useful tool for plant breeders to detect this trait.

Relative decreases in corn yield due to water stress (as indicated by increased canopy temperature) were similar for all of the corn hybrids tested. However, the maximum yield potential varies considerably from hybrid to hybrid. Thus, accurate estimates of corn grain yields with remotely sensed data require knowledge of each hybrid's yield potential and of the canopy temperature stress experienced.

Population Study

Extreme population density differences did not appear to cause differences in IRT canopy temperature among well watered subplots (Fig. 5). No differences in canopy temperature were observed among non-irrigated subplots if the population difference was small (Fig. 6). Canopy temperature differences of 1-2 C were observed in non-irrigated and partially irrigated subplots when population differences were large (Figs. 7 and 8). The areas of higher population were consistently warmer than were the lower population areas. The increased canopy temperature in the higher population subplots indicates that these plants were experiencing greater water stress. This effect is expected since competetion for water is greater in higher

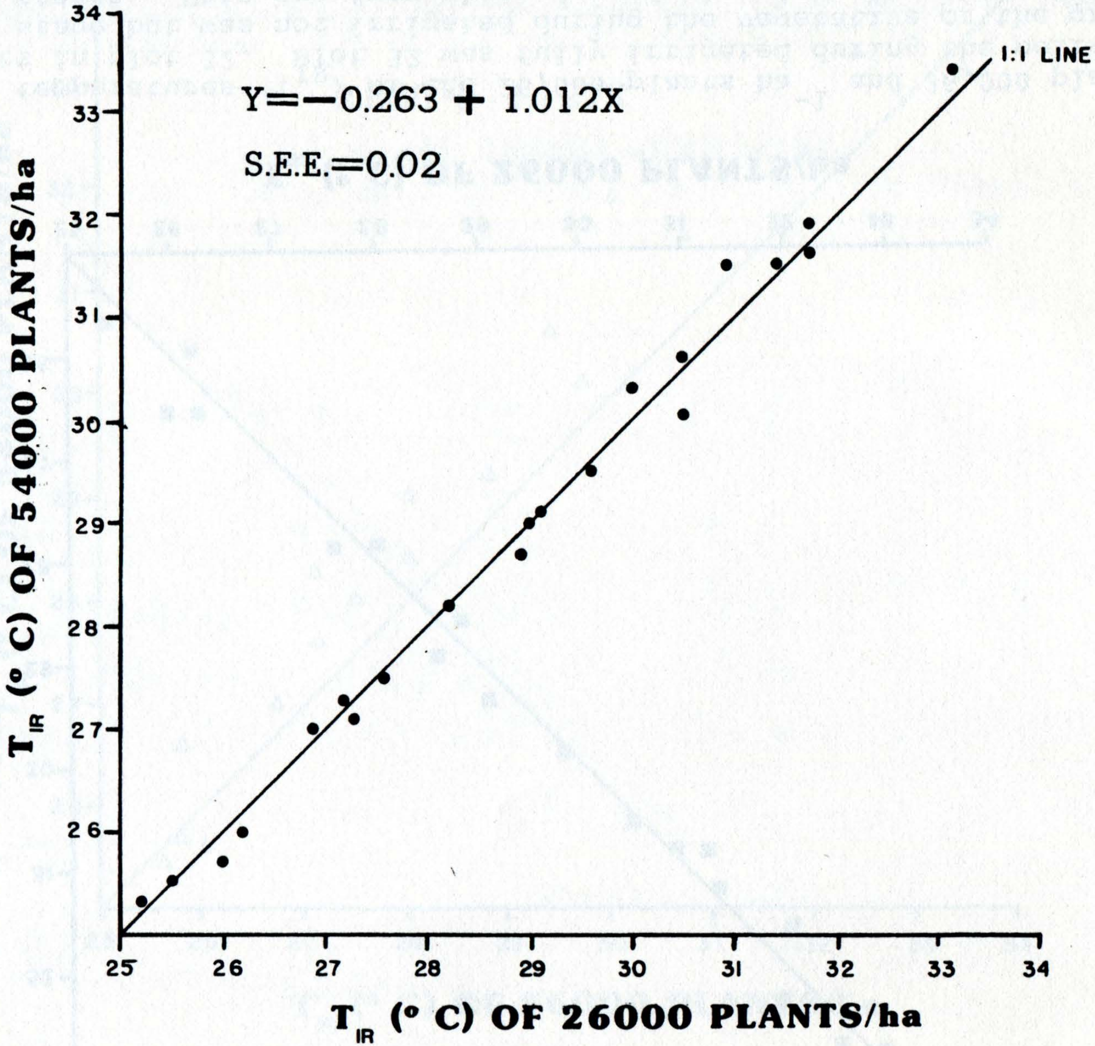

Fig. 5. Canopy temperatures (T_{IR}) of the 26,000 plants ha^{-1} and 54,000 plants ha^{-1} subplots in plot 29 which was fully irrigated. Data are from clear days during July 25 to September 5, 1979.

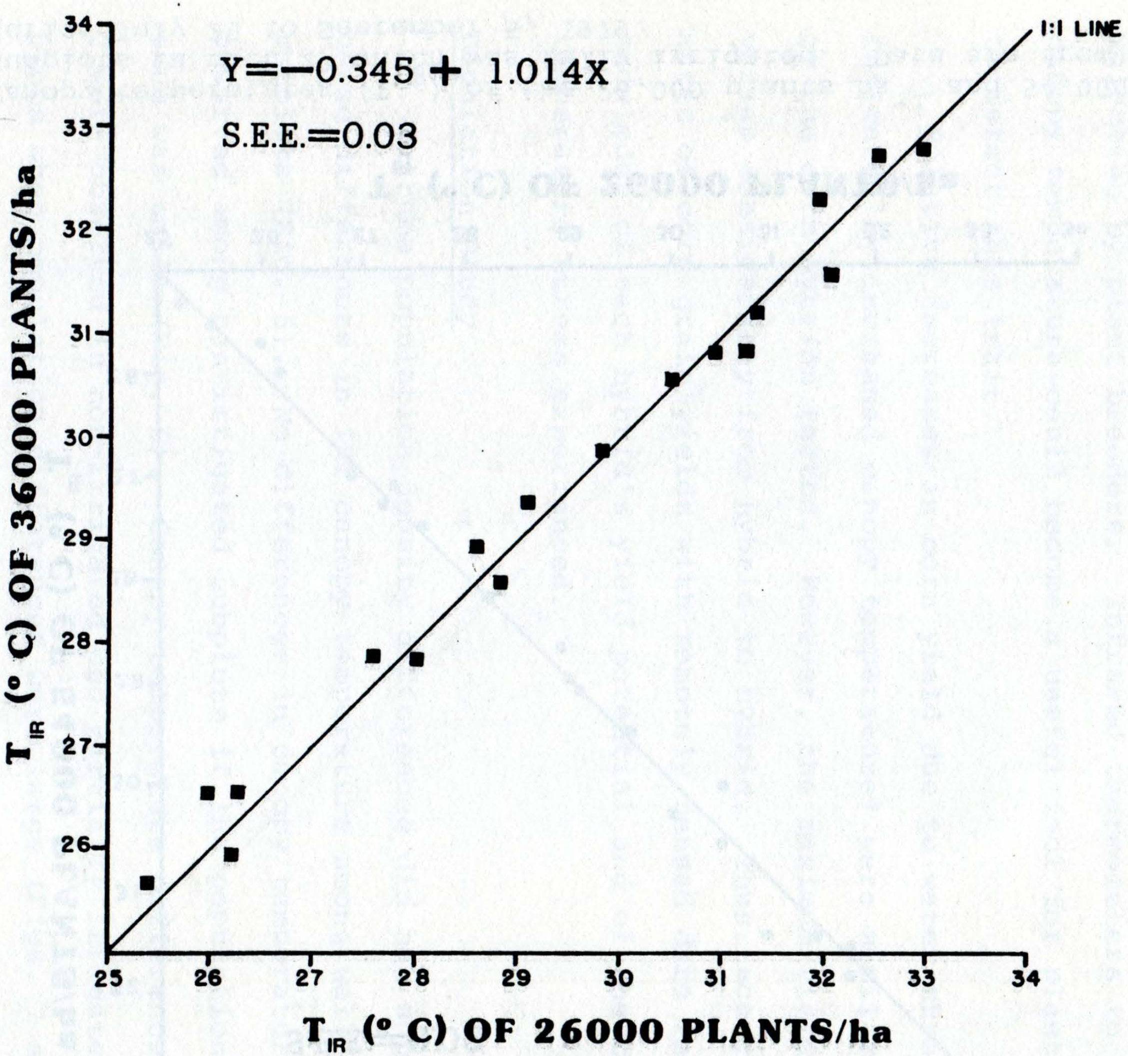

Fig. 6. Canopy temperatures (T_{IR}) of the 26,000 plants ha^{-1} and 36,000 plants ha^{-1} subplots in plot 32. Plot 32 was fully irrigated during the pollination growth stage but was not irrigated during the vegetative or the grain-fill growth stages. Data are from clear days during July 25 to September 5, 1979.

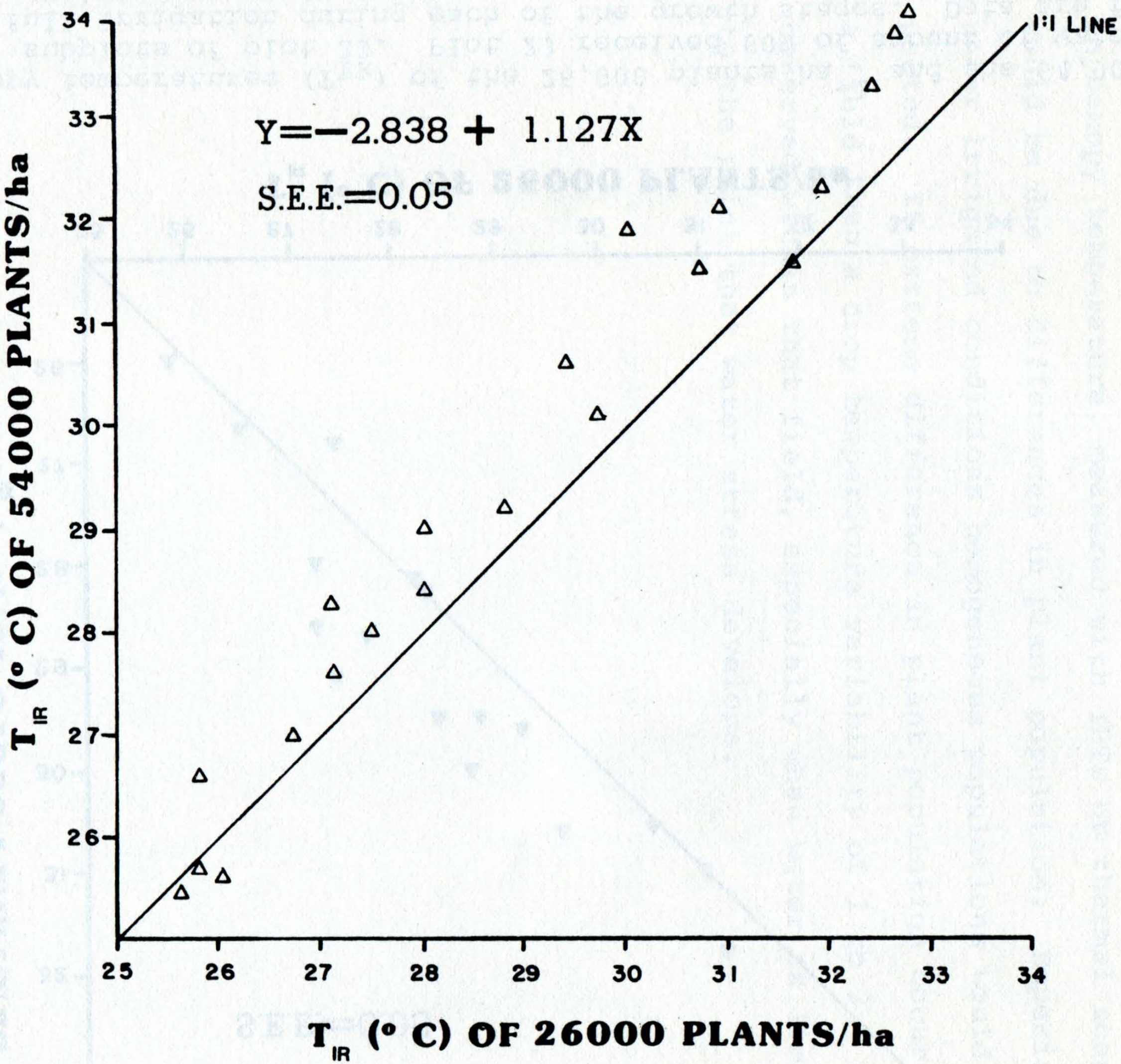

Fig. 7. Canopy temperatures of the 26,000 plants ha^{-1} and the 54,000 plants ha^{-1} subplots in plot 27. Plot 27 received no irrigation during the growing season. Data are from clear days during July 25 to September 5, 1979.

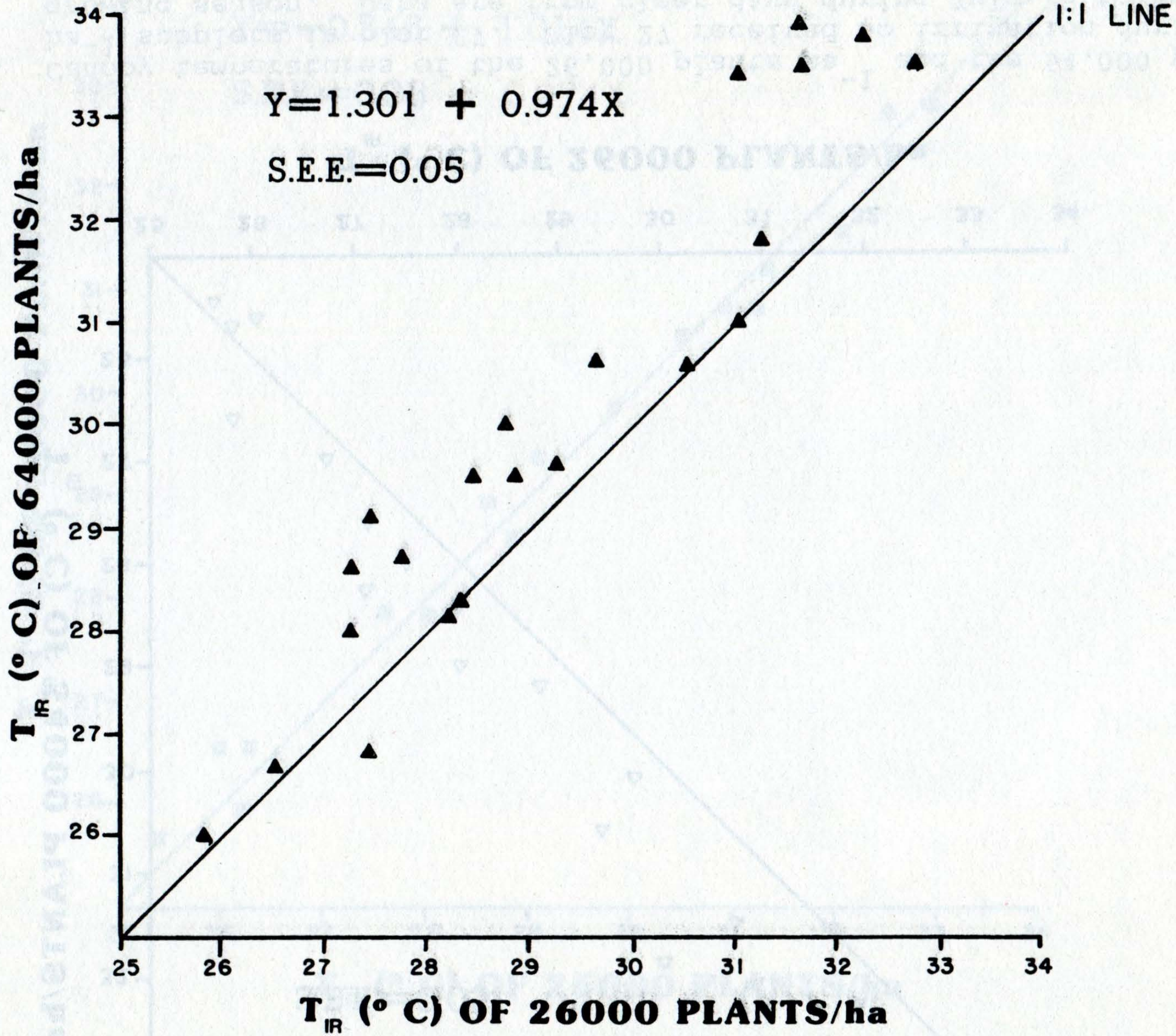

Fig. 8. Canopy temperatures (T_{IR}) of the 26,000 plants ha^{-1} and the 64,000 plants ha^{-1} subplots of plot 23. Plot 23 received 60% of amount of water required for full irrigation during each of the growth stages. Data are from clear days during July 25 to September 5, 1979.

population. This effect leads to more rapid consumption of any available soil moisture which, in turn, causes more pronounced water stress resulting in warmer plants.

In commercial fields of corn it is unlikely that variations in canopy temperature, measured with IRTs or thermal scanners would be due to differences in plant population. Especially under irrigated conditions homogeneous populations would be expected. If extreme difference in plant population occur within a field then a crop temperature variability of 1 to 2 C may be observed within that field, especially when water is limiting to the point that water stress develops.